COMPOSITION AND PHENOLOGY OF MAYFLIES (EPHEMEROPTERA) EMERGING FROM STREAMS IN ALGONQUIN PARK, ONTARIO, CANADA

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ABSTRACT

The species composition and phenology of mayflies (Ephemeroptera) were studied at five sites in two streams in Algonquin Park, Ontario for three years. Sixty emergence traps operated during the ice-free season yielded 2,566 insects, representing a total of 29 species with only 7-14 species recorded from any one site. Total numbers of mayflies (1,534 individuals) captured at one station on Costello Creek (CC1) were greater than at four stations combined (1,032 individuals) on Mud Creek (MC 1, 2, 3, and 4). Eight species were common (>100 individuals): *Habrophlebia vibrans*, *Paraleptophlebia adoptiva*, *P. debilis*, *P. mollis*, *P. volitans*, *Baetis brunneicolor*, *Stenonema modestum* and *Stenacron carolina*; two were frequent (>40 ind.): *Baetis flavistriga* and *Stenonema vicrarium*. The remaining 19 species were either infrequent (>20, two species), rare (>10, 5 species) or scarce (<10, 12 species). Mayfly emergence density was correlated with discharge, temperature and lunar cycles within and among years.

INTRODUCTION

The mayfly fauna of central Ontario was the focus of several taxonomic and ecological studies during the 1930s and 1940s (e.g., Ide 1935, 1940, McDunnough 1931, 1933, Sprules 1947). Recently, with renewed interest in the Ephemeroptera as indicator organisms for environmental stresses, particularly acid precipitation, there has been a resurgence of studies from the area including information on mayfly life histories and distribution (Giberson and Hall 1988, Giberson and Mackay 1991, Hall et al. 1988, Hall and Ide 1987, Mackay and Kersey 1985, Rowe and Berrill 1989). Most of these studies have concentrated on nymphal growth and distribution, but information on emergence of the adults is also important, since emergence patterns represent the overall success and strategies of the species.

During 1984, 1985, and 1986, numerous emergence samples were collected from two streams in Algonquin Provincial Park, Ontario at the same sites sampled by Ide and Sprules in the early 1940s (Ide, 1940; Sprules, 1947). Data on effects of acid precipitation on the species composition of invertebrates within these poorly buffered streams were presented in Hall and Ide (1987) and Chmielewski and Hall (1993). The focus of this paper is the emergence patterns and phenologies of mayflies found during the 1984-86 sampling periods.

STUDY SITES

The streams chosen for this study are located in Algonquin Provincial Park, Ontario (45°33' N, 75°15' W; Fig.1). Costello Creek and Mud Creek flow over the granitic bedrock of the Precambrian Shield and are unpolluted, poorly buffered, low alkalinity streams flowing through the northern part of the mixed conifer and hardwood forest belt. Costello Creek arises as an outflow from Costello Lake and flows north to discharge into Lake Opeongo. Mud Creek flows south from its source into Galeairy Lake. Riparian vegetation consists of alder, birch, pine, balsam fir, cedar and spruce. Both streams are situated in the southeast portion of the park and are approximately 3 km apart (Fig. 1).

The sampling site on Costello Creek (CC1) was a first order site with an average width of 2.5 m, located 36.5 m below the outflow of Costello Lake. The traps were set up over a 50 m section of stream characterized by a fast current over a rubble and boulder substrate ending in a slow flowing, swampy area.

Three sites were sampled on Mud Creek (MC) during 1984, and four during 1985 and 1986. Mud Creek stations MC1, MC2, and MC3 (Fig. 1) are first order stream sites with rubble substrates. MC4, included in the sampling programme in 1985 and 1986, is a fourth or fifth order site with a sand and gravel stream bottom bed. Stations MC1, MC2, MC3 and MC4 correspond to stations 1, 2, 3, and 6 sampled by Sprules (1947).

MATERIALS AND METHODS

Chemical and Physical Measurements

Temperature and discharge were measured weekly from early May to early October during 1984-86 in Costello and Mud Creeks. Water samples were collected weekly and analyzed for chemical concentrations according to the procedures outlined by Locke and Scott (1986). Data for temperature, pH and discharge are presented here. Additional information on stream water chemistry is reported in Hall and Findeis (1996).

Insect Emergence Studies

Adult mayflies were collected in cone emergence traps (Fig. 2). Fifteen traps were set up at CC1 and MC1, and ten at each of the other sites. The traps covered 0.07 m^2 of stream bottom area and were constructed of 1.7 mm (15 mesh per inch) fibreglass window screening glued into a cone and fastened at the base to a 30 cm diameter ring of 12 mm PVC tubing. A 7 cm length of tubing projected through the apex of the cone and through the base of a 1 L Nalgene bottle,

containing a small amount of 70% ethanol. Each trap was suspended over the stream by a cord attached to an overhead support so the base ring floated on the surface (Fig. 2). Insects emerging into the trap migrated to the top of the cone and into the collecting bottle, then fell into the alcohol. Specimens were removed from the traps weekly by field technicians who unscrewed the bottle caps, poured the contents into vials and refilled the bottles with fresh ethanol. Cone traps were used in this study for ease of service, since they required only weekly handling. In earlier studies, Ide (1940) and Sprules (1947) used 1 yd^2 cage traps and emptied them daily (Chmielewski and Hall 1993).

Nomenclature and identification are in accordance with Edmunds et al. (1976) and the revisions of Allen (1980), Bednaryk and McCafferty (1979), and Flowers (1980).

RESULTS

Chemical and Physical Measurements

Stream discharge at the study sites was variable among years and stations (Fig. 3). Discharges at Costello Creek during the three-year study ranged between 7.6 and 1780 L/s. Runoff for MC1-MC4 were 0.250-450, 0.5-492, 3.73-1190, and 44.7-2290 L/s, respectively. The largest increase in runoff occurred during 1985 for both Costello and Mud Creeks. For all years, CC1 and MC4 had the highest discharge values and MC1 and MC2, the lowest. MC3 displayed intermediate levels.

Maximum-minimum temperatures were similar among years (1984-86) in Costello Creek, ranging between 2-30°C (Fig. 4). However, in Mud Creek, maximum temperatures were lower at all sites in 1985 relative to 1984 and 1986, likely because of increased discharge during 1985. The sites with the highest stream water temperatures were CC1 and MC1 (range: 0.5-31°C). MC2 had the lowest maximum temperatures (range: 1-24°C) while MC3 and MC4 had intermediate values (range: 0.5-27°C).

The pH fluctuations in Costello Creek during the study period ranged from 5.8-6.5 with an annual mean of 6.2 ± SE = 0.19 (Fig. 5). The depressions in pH were greater at most study sites in Mud Creek in 1985 compared to 1984 and 1986, indicating the opposite trend to that of discharge. MC1 displayed the greatest pH depressions from a mean of 6.3 in summer to as low as 4.9 in early spring (annual mean = 5.75 ± 0.035. MC2 and MC3, located downstream from MC1, had annual pH depressions ranging from 5.09 to 6.54 (annual mean = 6.10 ± 0.39) and from 5.11 to 6.43 (annual mean = 6.1 ± 0.22), respectively. The pH fluctuations observed at MC4 are more similar to those of CC1 with ranges of 6.79-5.56 (annual mean = 6.35 ± 0.26).

Abundance and Distribution

Twenty-nine mayfly species were identified from the five sites between 1984 and 1986, though only 7-14 species were recorded from any one site (Table 1). Numbers of emerging mayflies varied widely from year to year for all species, but emergence in 1985 was generally higher (CC1, MC1 and MC2) than either 1984 or 1986 and, for most sites, was lower than reported for the same sites between 1937 and 1941 (Table 2).

The most common families were the Leptophlebiidae, primarily *Habrophlebia vibrans, Paraleptophlebia adoptiva, P. debilis, P. mollis, and P. volitans;* the Baetidae, mainly *B. brunneicolor and B. flavistriga*, and the Heptageniidae, mainly *Stenonema modestum and Stenacron carolina* (Table 3). During 1984, 1985, and 1986, relative proportions within the major families remained fairly constant (Table 1), with leptophlebiids comprising 70%, 69.4% and 62% of the total population, baetids making up 11.4%, 14.6%, and 8.4%, and heptageniids accounting for 13%, 8%, and 11.2%, respectively. However, within families, there was much higher variability. Several species, including *Habrophlebia vibrans, Paraleptophlebia adoptiva, P. debilis, P. mollis, P. volitans, Baetis brunneicolor, Stenonema modestum, S. vicarium,* and *Stenacron carolina*, showed high fluctuations in abundance and relative proportions between the years (Table 1).

Eight species were found at all sites at least once during the study period: *Habrophlebia vibrans, Paraleptophlebia debilis, P. volitans, Leptophlebia nebulosa, Baetis brunneicolor, B. flavistriga, Stenonema modestum, and S. vicarium.* *Paraleptophlebia adoptiva* and *P. mollis* were largely restricted to CC1. *Baetis flavistriga* was also most common in CC1 with only a few individuals captured at the four MC sites for the duration of the study. *Baetis brunneicolor* and *Stenacron carolina* were most abundant at stations MC2 and MC3 (Table 1) and *P. debilis* at MC1 and MC2.

Adult females were collected in greater abundance for the dominant taxa (Table 3). More males than females were collected for only a few of the rare taxa (*Baetis pluto*, *Centroptilum convexum* and *Heptagenia pulla*).

Life Cycles and Phenology

In both Costello Creek and Mud Creek combined, the onset of emergence for adult mayflies occurred during the second or third week in May (Fig. 6) after snowmelt when the water was warmer. All species had begun to emerge by the beginning of July, and emergence was completed by early October (Fig. 6). No consistent pattern of emergence between years was noted, although for many species, the emergence was later, or extended longer in 1984 and 1986. Also, the onset of emergence was earlier for some species in 1986 than 1984-85.

The life cycle cannot be determined from emergence data alone, since similar emergence patterns may be seen between synchronous semivoltine and univoltine species (U) and between polyvoltine (M) and univoltine species with prolonged (p) emergence. Consequently, life cycle patterns were derived from the literature and are shown in Table 3. Most of the species have univoltine winter cycles (Uw=one year cycles, with nymphs overwintering), although two were semivoltine (2 year cycles, *Eurylophella funeralis* and *Habrophlebia vibrans*), and most of the Baetidae were probably polyvoltine (Mp=3 or more generations per year with prolonged

emergence, Figs. 7 and 8).

Leptophlebia cupida and *L. nebulosa* were the first species to emerge in the study streams, and these species showed very short, clearly defined emergence periods (Figs. 6 and 8). Of the summer emerging species, the ephemerellids (*E. invaria, E. funeralis, E. excrucians, E. subvaria,* and *E. bicolor*), *Heptagenia pulla, Centroptilum convexum,* and *Leptophlebia johnsoni* all had a synchronous emergence. Most of the heptageniid and baetid species showed prolonged emergence over the whole summer.

For species showing prolonged emergence periods, there was a general pattern of more than one clearly defined emergence peak (Figs. 7 and 8). For polyvoltine species (some Baetidae, eg., *B. brunneicolor, B. flavistriga, B. tricaudatus*), the multiple emergence peaks are associated with successive generations. To try to determine the cause of secondary emergence peaks for the uni- and semivoltine species, emergence data were pooled and compared to the phases of the moon. There appeared to be a pattern with the lunar cycle, with most emergence peaks occurring within a few days of the full moon (Fig. 9).

DISCUSSION

Correlations existed between mayfly emergence densities and pH, discharge, and to a lesser extent, temperature variation. Increased mayfly emergence during 1984-86 was most strongly correlated with increased discharge in 1985 for all stations. Harper and Harper (1984) and Harper (1990) have shown that emergence is greater with higher discharge in streams in Ontario and Québec. The reduced emergence densities and species at some sites with greater pH depressions (MC1) compared to those with smaller depressions point to the importance of pH as well. Reductions in mayfly species with low pH have been reported by Hall (1990; 1994) for other south-central Ontario streams. Strong correlations between temperature and emergence were reported by Sprules (1947). Possibly the temperature measurements recorded in the present study were not detailed enough to show patterns similar to Sprules' studies.

Abundance and Distribution

The numbers of emerging mayflies trapped per m^2 vary widely on an annual basis, in different localities, and in streams of different size. Harper and Harper (1982) and Harper (1990) reported mean values of 100-1200/m^2 and 85-364/m^2, respectively, in Quebec soft-water stream and river systems. At two headwater sites in Manitoba, Flannangan et al. (1990) observed emergence densities of mayflies between 368/m^2 and 630/m^2 and Ide (1940) recorded higher numbers for emergence of mayflies in a southern Ontario stream (mean=6500/m^2). Emergence densities in this study showed high variability between sites and between years (Tables 1 and 2). The Costello Creek site and Mud Creek site 2 (MC2) showed the highest densities, at least twice that of any other site, and year to year differences were about the same magnitude. Costello Creek is two to three times wider than MC2 which would partially account for its two times greater density of adult mayflies. Higher nutrient concentrations and overall lower water temperatures at CC1 and MC2 relative to MC1, MC3 and MC4 may also contribute to greater emergence densities.

At the same sites as in the present study, Sprules (1947) and Ide (pers. comm.) found generally higher numbers of emerging mayflies half a century ago than were found in 1984-86. The apparent decrease in the mayfly population may have resulted from environmental stresses, such as acidification (Hall and Ide 1987), or may reflect the efficiencies of the types of traps used. Leuty (1988) evaluated the relative efficiencies of cage and cone traps, but the results were inconclusive. Emerging insects avoid shaded areas (Kimmerle and Anderson 1967, Boerger 1981, Davies 1984). Scott and Opdyke (1941) suggested that smaller traps were more efficient because insects can more effectively avoid large areas of shade. However, insects emerging at the edges of traps may move to the outside to avoid the shade, and Morgan et al. (1963) postulated that the edge effect would be more pronounced in small traps since they have a higher edge to area ratio. In a separate study using both types of traps in Mud Creek and Costello

Creek, we found that both showed the same emergence pattern, though the cage traps caught more rare species (Chmielewski and Hall 1993).

Seven to fourteen mayfly species were found at each site in given years, though when data from all years was pooled for each site, the species richness was very similar, at 16-19 species (Table 1). Harper and Harper (1984) reported 4-18 species per station at Salem Creek, Ontario, and up to 29 per station in Quebec (Harper and Harper 1982), largely depending upon stream size and discharge (Harper 1978). As the Algonquin Park streams were all quite similar in size, they showed similar species richness in 1984-86 to the Quebec streams, although this diversity in Algonquin was generally lower than that found in 1937-41 (Sprules 1947, Hall and Ide 1987). The lower diversity in individual years and in 1984-86 relative to 1937-41 may be due to trap efficiencies, since the cone traps did not effectively sample rare species.

Leptophlebiids, primarily *Habrophlebia vibrans* and *Paraleptophlebia* spp., were the dominant mayfly family in all the stream sites, accounting for >50% of emergence in most sites in most years. Baetids and Heptageniids were also common.

Life Cycles and Phenology

Emergence patterns reflect the overall success and strategy of insect species. Mayflies in temperate areas show two distinct patterns of emergence (Harper and Harper 1982, Harper and Magnin 1971). An early spring emergence is associated with univoltine and semivoltine species (and the first cohort of polyvoltine species) that overwinter as mature or nearly mature nymphs. Other mayflies that must complete nymphal growth in spring and summer, or those that are the second or third generations of polyvoltine species, do not start emerging until later in the summer or fall. Emergence in spring is typically highly synchronous, while the summer emergence pattern is usually more dispersed (Harper and Harper 1982). The prolonged summer emergence may result from delayed egg hatching responses or differences in nymphal growth rates in

univoltine or semivoltine species (Brittain 1979, 1982) or it may be caused by emergence of successive cohorts in polyvoltine species (Harper and Harper 1982).

Leptophlebia cupida and *L. nebulosa* were the first species to emerge in the study streams, and showed a very short and synchronous emergence period. The same pattern was seen in Quebec (Harper and Harper 1982, Harper 1990) and in nearby Muskoka region streams (Giberson and Mackay, 1991). *Leptophlebia cupida* is univoltine and overwinters as a nearly mature nymph, with most of the nymphal growth occurring in the fall (Clifford et al. 1979, Coleman and Hynes 1970, Giberson and Mackay, 1991). These species were not noted in the 1937-41 surveys (Sprules 1947, Hall and Ide, 1987) and were relatively rare in the present study, probably because the sampling areas were mainly fast-water reaches of streams, and *L. cupida*, at least, is more characteristic of slower moving reaches (Harper and Harper 1982). *Leptophlebia cupida* nymphs are known to migrate upstream into slow-flowing reaches and tributaries just prior to emergence (Clifford et al. 1979), so their presence may be due to migration patterns.

Habrophlebia vibrans occurred at all stations, although it was most common at the Costello Creek station and at station MC3 on Mud Creek. Both sites were approximately the same width. Giberson and Mackay (1991) and Harper and Harper (1982) also noted that *H. vibrans* was more common in larger stream reaches, and Sprules (1947) found it to be most common at his stations 2 and 3 (MC2 and MC3 in this study). Lauzon and Harper (1986) indicated a 2 year cycle for *H. vibrans* in Quebec, while Huryn and Wallace (1987) found a 16 month cycle in North Carolina. The duration of emergence seems to vary with latitude. In Quebec, the emergence period was only 4-5 weeks (Harper and Harper 1982) compared to 6-8 weeks in Algonquin Park (though some stragglers were still emerging after 12 weeks) and 13-17 weeks in South Carolina (Carlson 1973). However, Huryn and Wallace (1987) also reported a short, synchronized emergence in North Carolina lasting only 5-6 weeks.

Representatives of the genus *Paraleptophlebia* were common at most stations. *Paraleptophlebia* species are generally univoltine with either winter cycles, where the nymphs overwinter, or

summer cycles, where nymphal growth and emergence occur during summer and the overwintering stage is probably the egg (Clifford 1982). *Paraleptophlebia mollis* and *P. adoptiva* showed univoltine winter cycles in Ontario (Corkum 1978, Giberson and Mackay, 1991) and *P. volitans* had a univoltine winter cycle in North Carolina (Smock 1988) and probably also in Quebec (Harper and Harper 1982). All of these species showed relatively extended emergence periods in the Algonquin Park streams. *Paraleptophlebia debilis* exhibited a univoltine summer cycle in Alberta (Clifford 1969) and in central Ontario (Giberson and Mackay 1991), and Sprules (1947), Harper and Harper (1982), Harper (1990), Grant et al. (1997) and Flannagan et al. (1990) reported late season emergence peaks, indicating a presence of growing nymphs throughout the summer. We found similar results with a late-season emergence of *P. debilis* in the Algonquin study streams.

Ephemerellids are also reported to be mainly univoltine winter species (Clifford 1982). *Eurylophella funeralis*, however, has been reported to have a semivoltine cycle in the north-eastern United States (Fiance 1978), and in central Ontario (Giberson and Mackay 1991), and *Serratella* species may have either univoltine winter or summer cycles (Clifford 1982). All the ephemerellids in the Algonquin Park streams began emerging fairly early in summer, a pattern typical of species that spend the winter as nearly mature nymphs.

Baetids have been reported to be largely polyvoltine, with one generation overwintering as nearly mature nymphs, followed by two or more summer generations (Clifford 1982). Consequently, the emergence pattern for most baetids is a prolonged one, dispersed over the whole summer. Grant et al. (1997) indicated a similar polyvoltine pattern based on emergence of *B. tricaudatus* in Pennsylvania, but concluded that *B. flavistriga* may be bivoltine in that location. Flannagan et al. (1990) recorded continuous emergence of *B. brunneicolor*, *B. flavistriga* and *B. tricaudatus* from May to September, suggesting multiple generations. In the present study, only *Centroptilum convexum,* which is probably univoltine with a single, synchronous emergence early in the summer, deviated from this pattern.

Heptageniids usually have univoltine winter cycles (Clifford 1982) with extended emergence periods relating to differences in nymphal growth and/or delayed egg hatching (Flowers and Hilsenhoff 1978). All the species found in Mud Creek and Costello Creek showed prolonged emergence periods. Similar results were found for five coexisting heptageniid species in a hard-water stream in southern Ontario (Rowe and Berrill 1989).

Many of the species in the study streams showed extended emergence periods, and of these, most showed several clearly defined emergence peaks over the summer. In polyvoltine species, such as many of the Baetidae, these peaks refer to the emergence of successive generations in the streams. However, univoltine species, such as some of the *Paraleptophlebia* and the heptageniids, do not produce successive summer generations, so must be responding to environmental factors. No consistent pattern was found between temperature and emergence during the summer period, but an apparent pattern was noted between emergence and lunar phase. Most of the emergence peaks occurred within a few days of the full moon. Elliott (1965) demonstrated increased activity in mayfly nymphs when the effects of moonlight were felt, and the life cycle of the tropical mayfly *Povilla adusta* Navas is synchronized with lunar rhythms (Hartland-Rowe 1958).

SUMMARY

1. Twenty-nine species of adult mayflies within four families (Leptophlebiidae, Baetidae, Heptageniidae amd Ephemerellidae) were collected from five stations in two Algonquin Park streams between 1984 and 1986.

2. The combined number of mayflies collected from one station in Costello Creek was greater than the numbers collected from four stations from Mud Creek.

3. Numbers of emerging mayflies were correlated to variable discharge, temperature, pH levels and lunar periodicity during the three-year study.

4. Mayfly emergence was lower at most stations in 1984-86 than reported for the same sites between 1937 and 1941.

5. The emergence of mayfly adults occurred during the second or third week in May and was completed by early October.

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Table 1. Total numbers of species of mayflies collected from each site of Costello Creek (CC1) and Mud Creek (MC1-MC4) stations in 1984, 1985 and 1986.

	CC1			**MC1**			**MC2**			**MC3**			**MC4**		**TOTAL**		
Species	84	85	86	84	85	86	84	85	86	84	85	86	85	86	84	85	86
Ephemerella excrucians				2	3										2	3	
E. invaria				1	1	1							1		1	2	1
E. subvaria		1					1	2	2		3				1	6	2
Eurylophella bicolor				1					2						1		2
E. funeralis	3				1						2				3	3	
Serratella sordida											1		4			5	
Habrophlebia vibrans	283	346	110	4	1	1	12	2	3	32	86	18	8	2	331	443	134
Paraleptophlebia adoptiva	138	22	31			1			9						138	22	41
P. debilis			1	8	23	1	59	122	10	2			2	1	69	147	13
P. mollis		274	11													274	11
P. volitans	22	27	15			9			75			1		1	22	27	101
Leptophlebia cupida		4	9		2	3					2	1		2		8	15
L. johnsoni		3	8				1								1	3	8
L. nebulosa	7	4	2	8		1			2	3	1			2	18	5	7
Baetis brunneicolor			5	3			34	155	5	24			1	5	61	156	15
B. flavistriga	24	29	22			1	3			3		2	2	1	30	31	26
B. pluto	1														1		
Baetis sp.			1									1					2
B. tricaudatus		4	6			1						1	3	1		7	9
Centroptilum convexum					3						1		3			7	
C. semirufrum										1	1				1	1	
Siphlonurus alternatus													4			4	
S. quebecensis					8			9			1					18	
Stenonema modestum	67	32		1			11	22	2	14	6		1		93	61	2
S. vicarium			17		1	2			3	8		6	2	4	8	3	32
Stenacron i. canadense	2								2	3				3	5		5
S. carolina			3				14	39	27			16		16	14	39	53
Heptagenia pulla									2								2
Leucrocuta hebe									10								10
TOTALS	547	746	241	28	43	21	135	351	154	90	104	46	31	29	800	1275	491
# of species per year	9	11	14	8	9	10	8	7	14	9	10	8	11	11	19	23	21
TOTAL # species- all years		19			17			17			19		16			29	

Table 2. Numbers of Ephemeroptera per m^2 collected in emergence traps. Data for 1937-41 for Costello Creek are taken from Ide (pers comm); those for Mud Creek from Sprules (1947). Stations MC1, MC2, MC3 and MC4 correspond to stations 1, 2, 3, and 6 sampled by Sprules.

YEAR	CC1	MC1	MC2	MC3	MC4
1937	5069	-	-	-	-
1938	5540	70 *	-	1133	68
1939	4381	673	598	-	232
1940	3858	-	-	558	76
1941	4361	-	-	-	
1984	520	27	193	129	-
1985	709	41	501	149	44
1986	229	20	220	66	42

* Station 1 dried up on July 17 in 1938.

Table 3. Sex ratios and Life cycle (LC) patterns of mayflies collected from Costello and Mud Creek, all stations combined. Uw= univoltine (one generation per year) winter cycle; Us= univoltine summer cycle; Mp= polyvoltine (3 of more generations per year) cycles; 2Y= semivoltine (one generation per 2 years) cycle.

Species	LC	Source	Male	Female
Family Ephemerellidae				
Ephemerella excrucians Walsh	Uw	1	-	5
E. invaria Walker	Uw	1	1	3
E. subvaria McDunnough	Uw	1	-	7
Eurylophella bicolor Clemens	Uw	1	1	2
E. funeralis McDunnough	2Y	2, 3	2	4
Serratella sordida McDunnough	Uw	1	-	5
Family Leptophlebiidae				
Habrophlebia vibrans Needham	2Y	3, 4	396	512
Paraleptophlebia adoptiva McDunnough	Uw	3	91	115
P. debilis Walker	Us	3, 9	87	142
P. mollis Eaton	Uw	10	110	175
P. volitans McDunnough	Uw	6	60	90
Leptophlebia cupida Say	Uw	3, 4	3	21
L. johnsoni McDunnough	Uw	1	4	8
L. nebulosa Walker	Uw	1	6	24
Family Baetidae				
Baetis brunneicolor McDunnough	Mp	9, 10	85	147
B. flavistriga McDunnough	Mp	1, 9. 10	32	55
B. pluto McDunnough	Mp	1	1	-
Baetis sp.	Mp	1	1	1
B. tricaudatus McDunnough	Mp	1, 7, 8, 9, 10	3	10
Centroptilum convexum Ide	Uw	1, 9. 10	5	2
C. semirufrum McDunnough	?	-	-	1
Family Heptageniidae				
Stenonema modestum Banks	Uw	5	57	99
S. vicarium Walker	Uw	5	16	27
Stenacron interpunctatum canadense Walker	Uw	1, 5	3	7
S. carolina Banks	Uw	1	44	62
Heptagenia pulla Clemens	Uw	1	2	-
Leucrocuta hebe McDunnough	?	-	5	5

1. Clifford 1982
2. Fiance 1978
3. Giberson and Mackay 1991
4. Lauzon and Harper 1988
5. Rowe and Berril 1989
6. Smock 1988
7. Dobrin and Giberson 2003
8. Grant, Burian and Masteller 1997
9. Flannagan, Cobb and Friesen 1990
10. This study

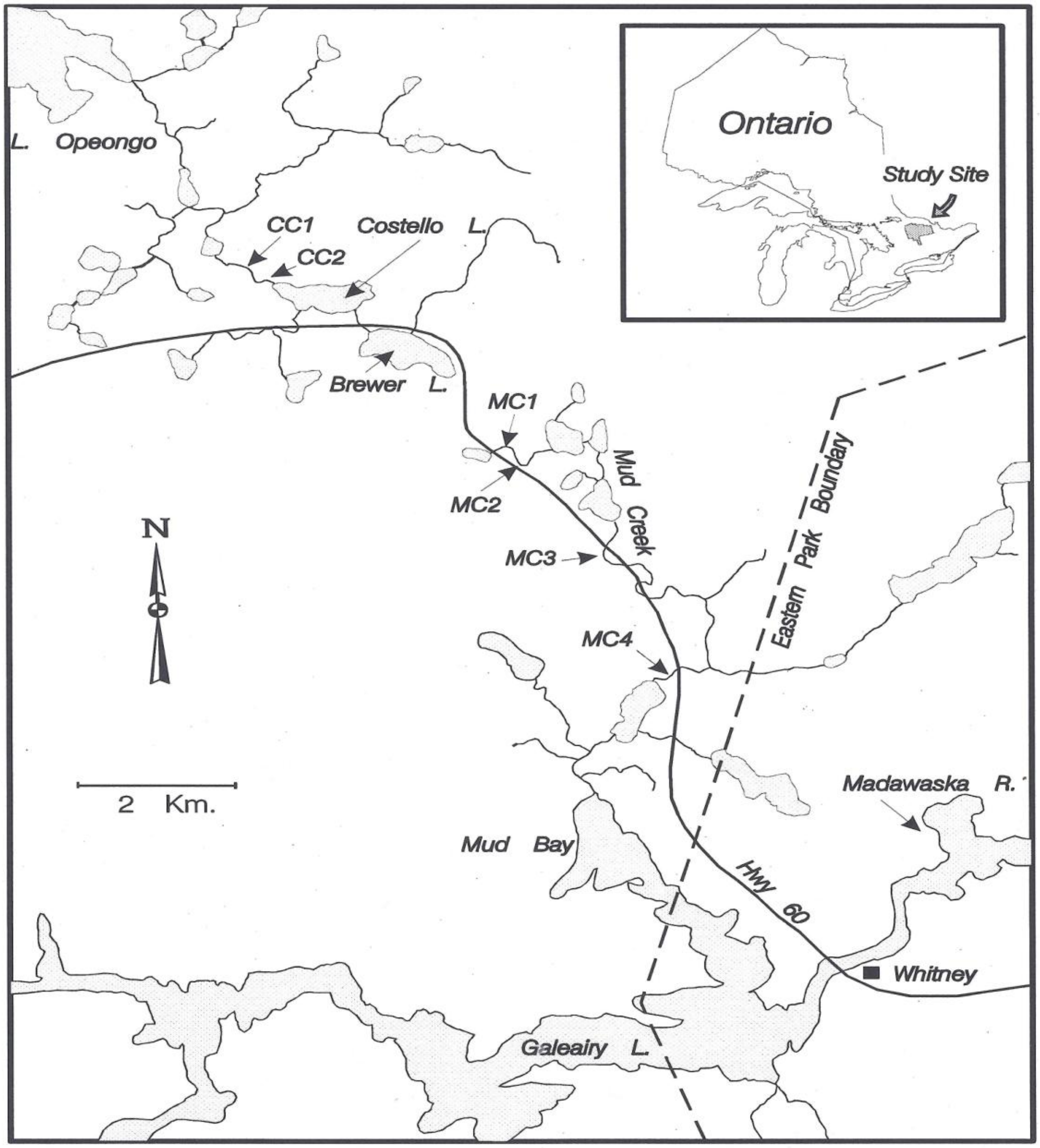

Figure 1 Map of study area in Algonquin Provincial Park showing sampling sites

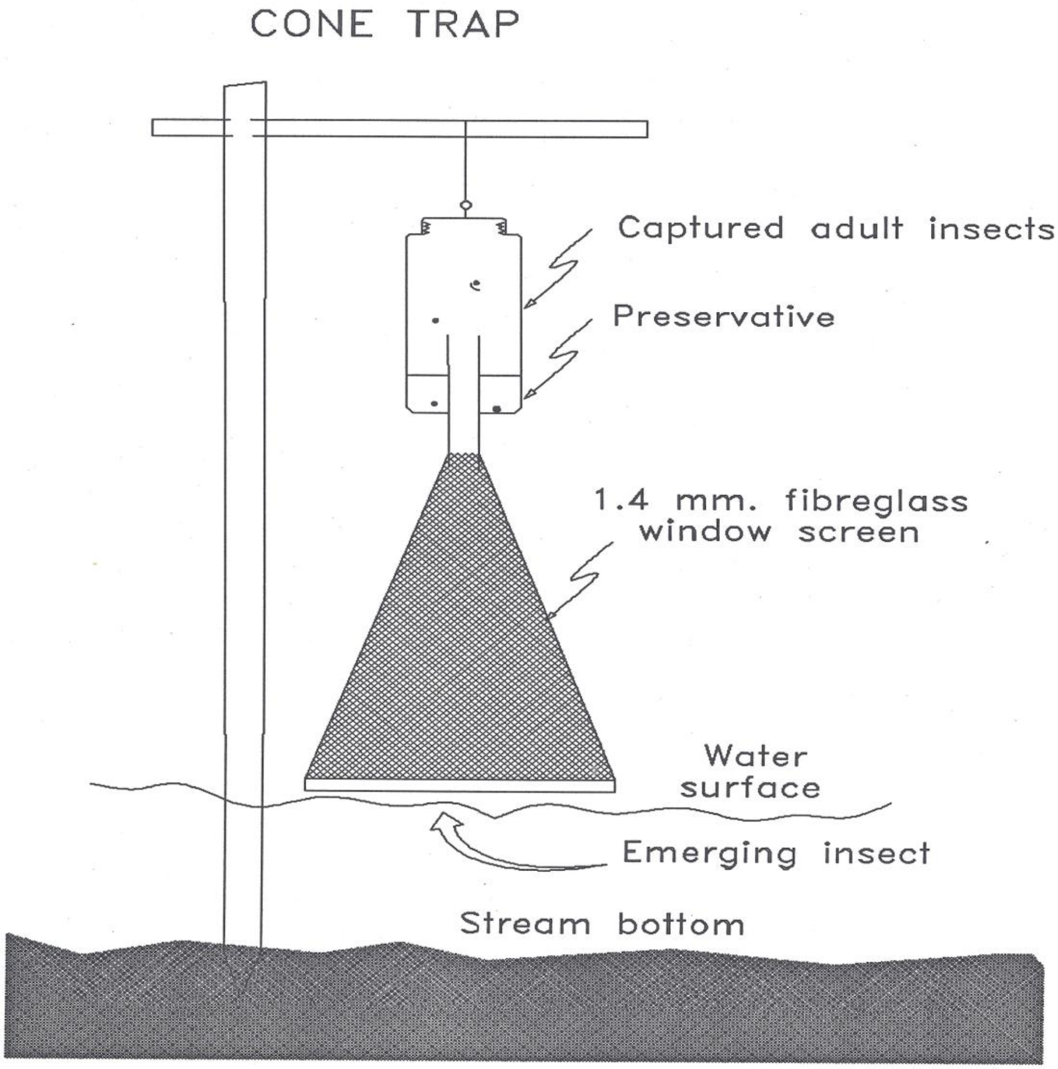

Figure 2 Emergence trap used to collect adult mayflies

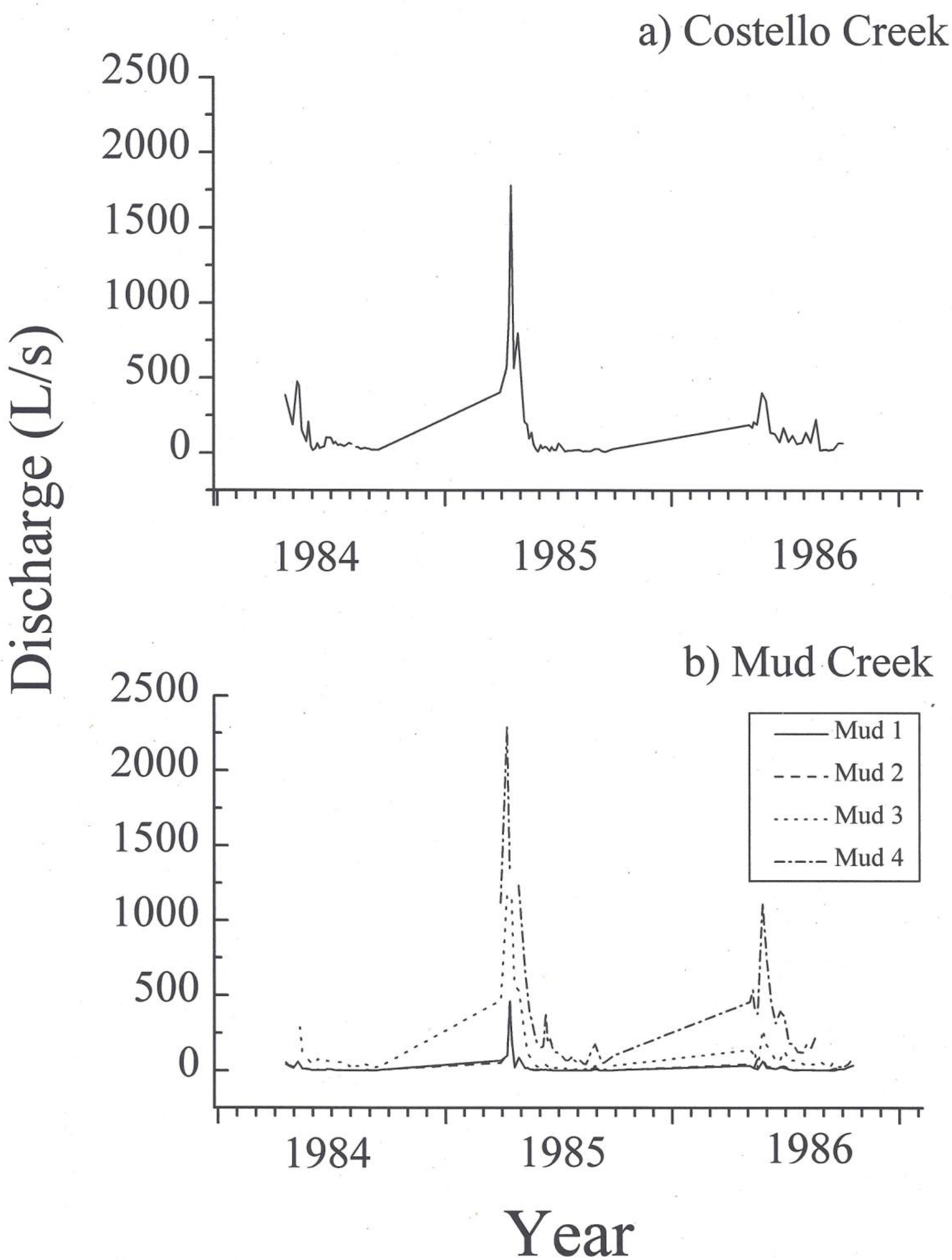

Figure 3 Discharge (L/s) for Costello Creek (CC1) and Mud Creek (MC1, MC2, MC3, MC4) during 1984-86

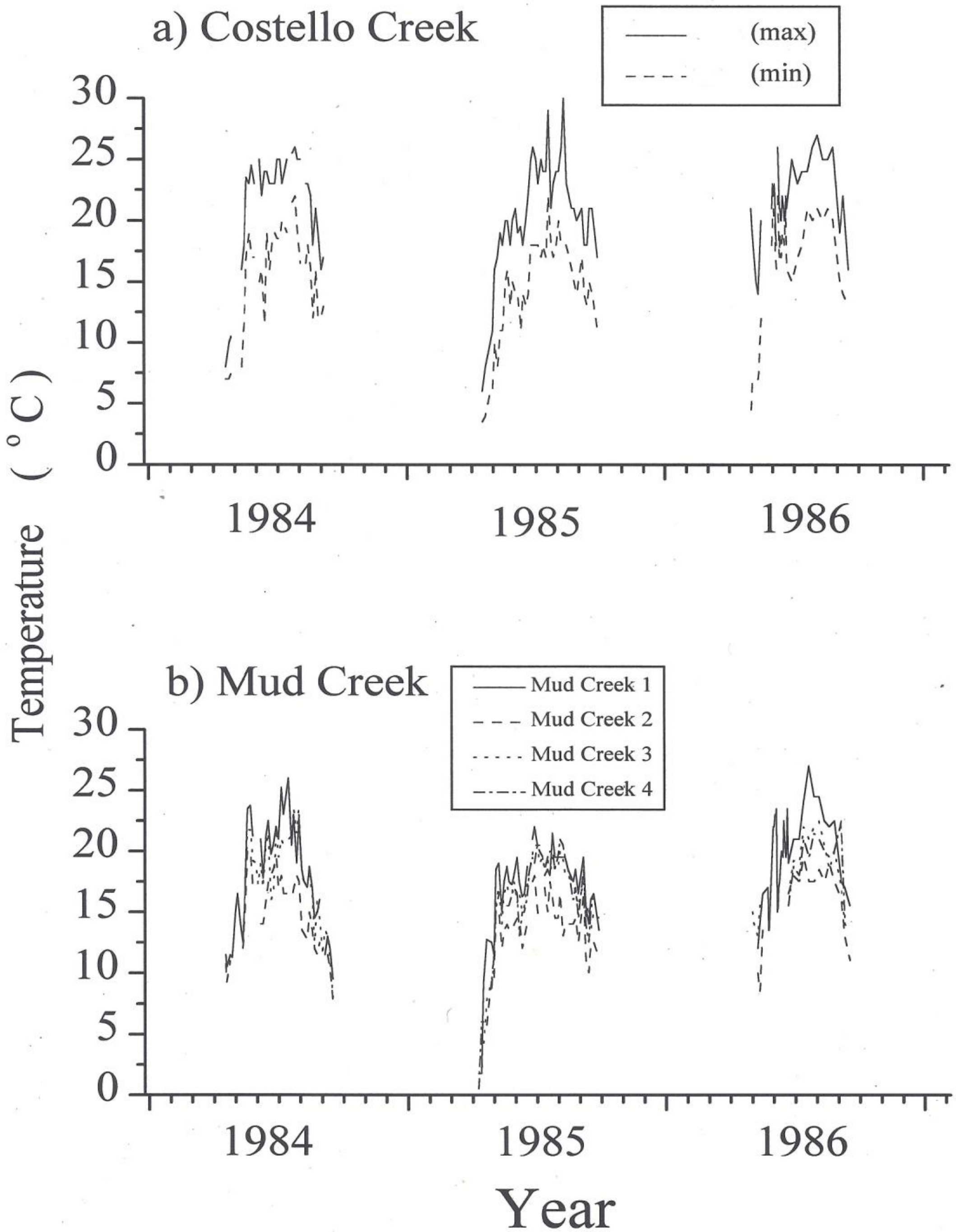

Figure 4 **Maximum-minimum temperatures at Costello Creek and maximum temperatures at MC1-MC4 during 1984-86**

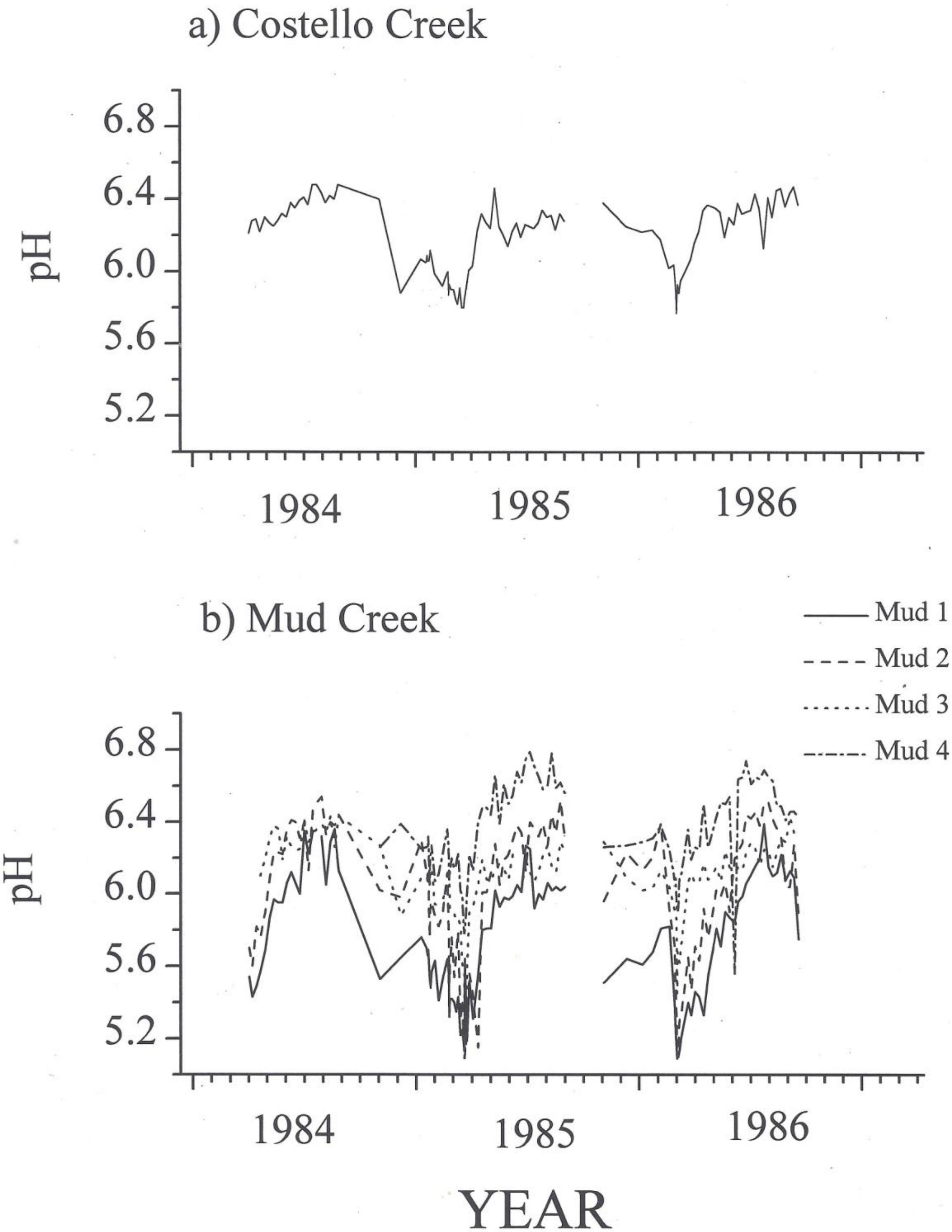

Figure 5 Stream pH levels for Costello Creek (CC1) and Mud Creek (MC1-MC4) during 1984-86

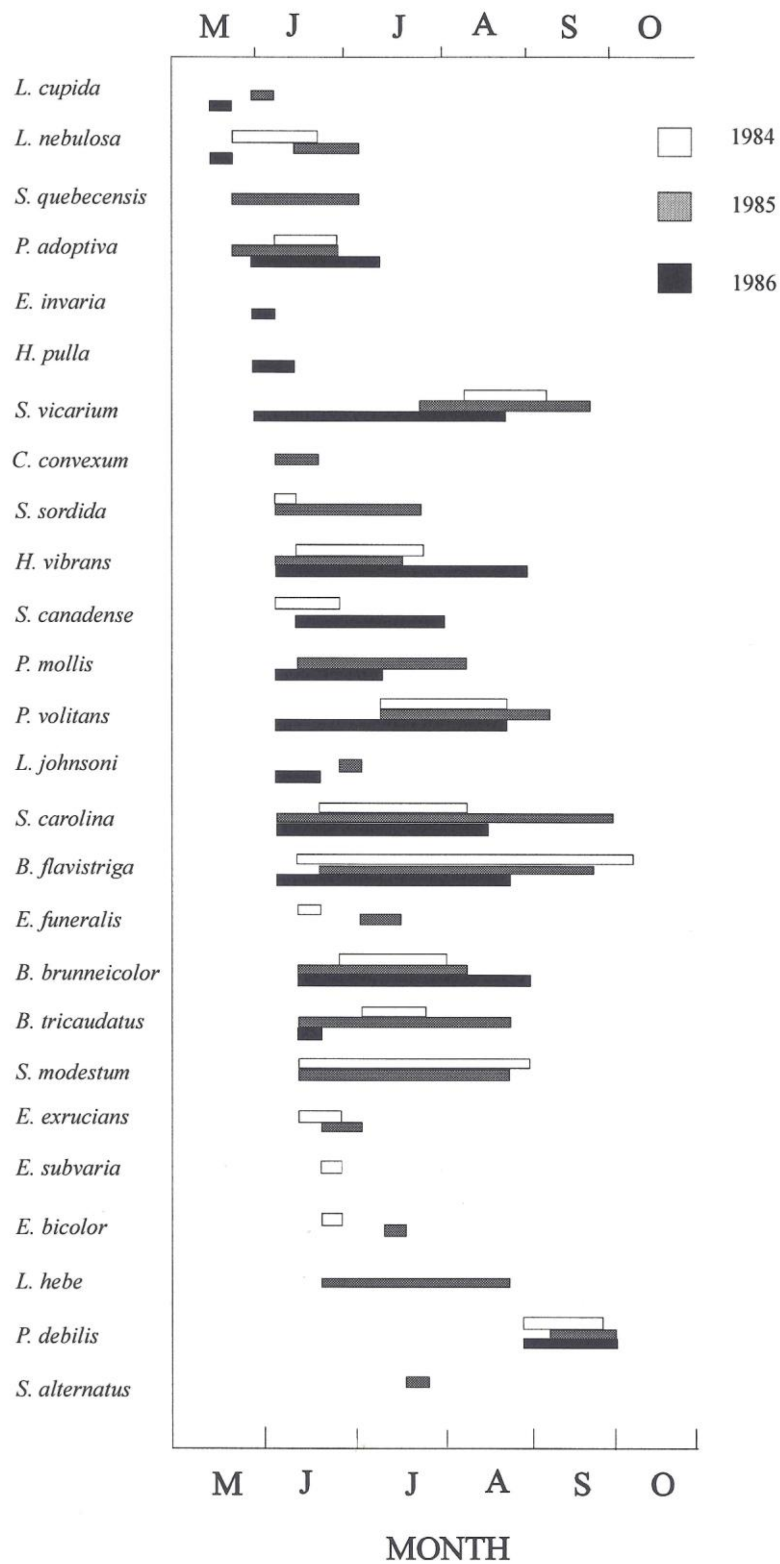

Figure 6 Sequence of emergence from May to October for adult Ephemeroptera in Mud Creek and Costello Creek for 1984, 1985, and 1986, all samples pooled

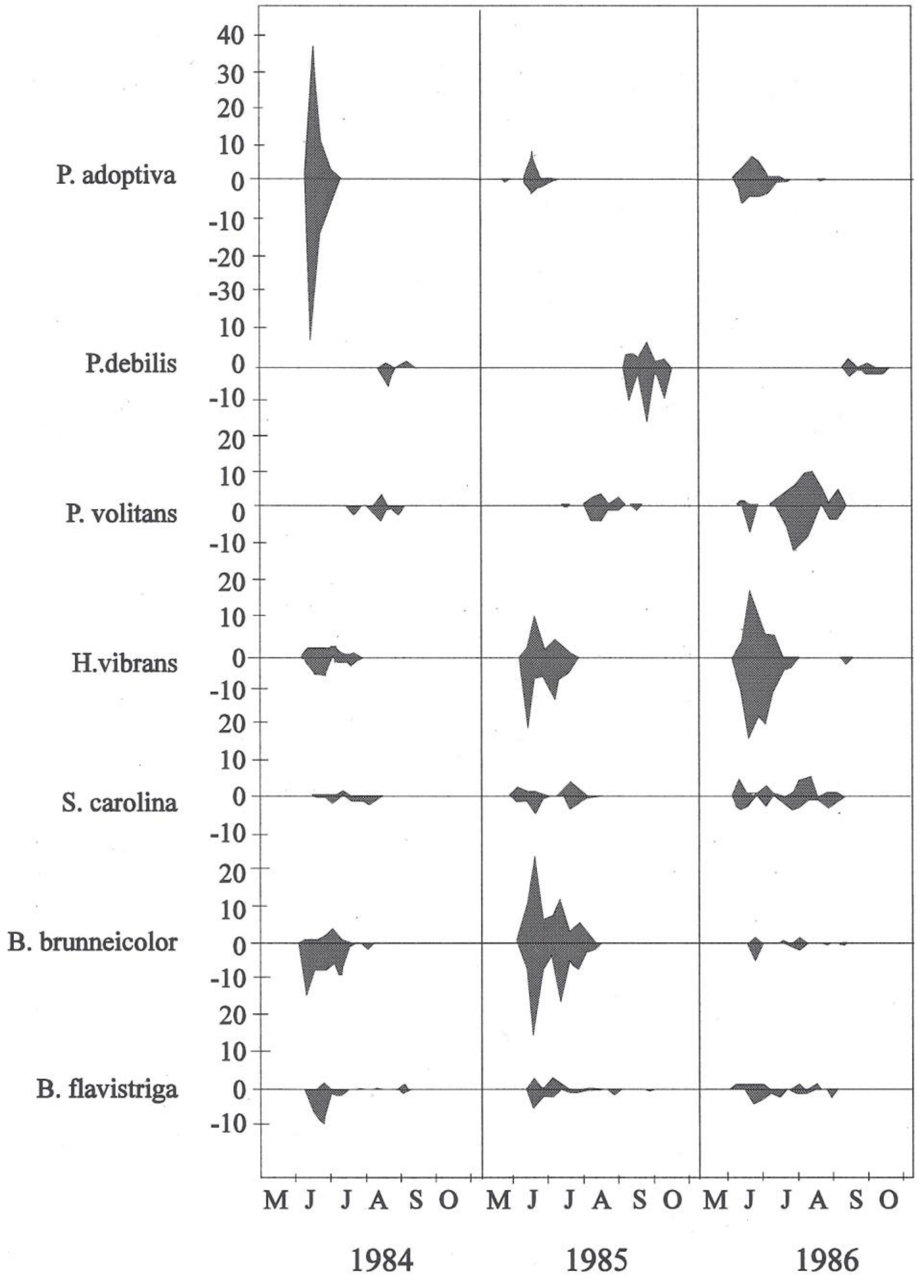

Figure 7 Emergence patterns of selected mayfly species from Algonquin study streams during 1984-86. Upper part of each diagram represents males, lower part, females.

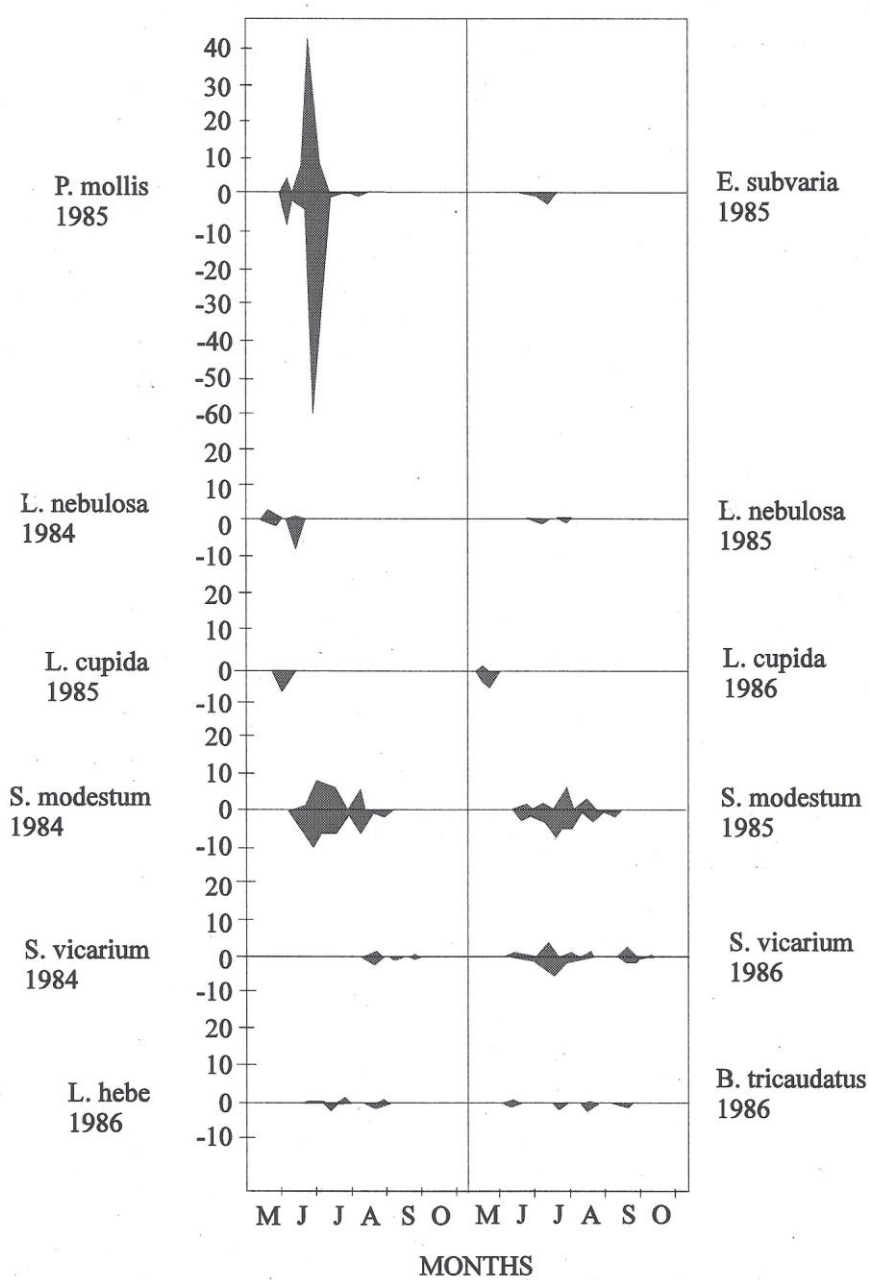

Figure 8 Emergence patterns of less common species of mayflies during selected years. Upper part of each diagram represents males, lower part, females.

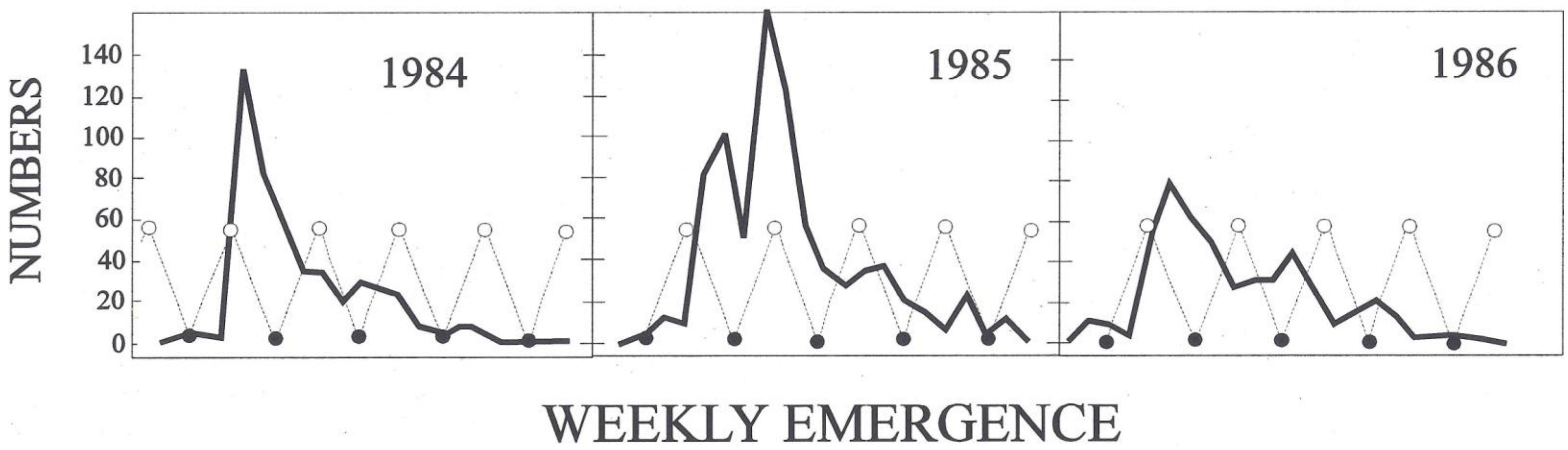

Figure 9 Emergence patterns (solid line) and lunar cycle between 1984-86. Open circles represent full moon and closed circles, no moon.